

The Development of Solar Astronomy In Malaysia

Z. S. Hamidi^{1,*}, N. N. M. Shariff², C. Monstein³

¹MARA University of Technology, 40450, Shah Alam, Selangor, Malaysia

²Academy of Contemporary Islamic Studies (ACIS), MARA University of Technology,
40450, Shah Alam, Selangor, Malaysia

³Institute of Astrophysics, ETH, Zurich, Switzerland

*E-mail address: zetysh@salam.uitm.edu.my

ABSTRACT

Monitoring the Sun reveals a variety of fascinating and complex physical phenomena which are being studied mainly by analyzing its emission. Solar activity has an impact with space weather. The characteristic features of the climate of Malaysia are uniform temperature, very high humidity and copious rainfall. It has an average of temperature of 26.7 °C. Therefore, it is suitable to monitor the Sun. In following work, we will emphasize the development of solar astronomy in Malaysia. The ground based observation (i) optical and (ii) radio are the main region that we focused on. Optical observation has started earlier comparing with radio observation. In optical region it covers from 400 – 700 nm while in radio region, we focus from 45 MHz to 870 MHz. The number of observatories is increasing. A dedicated work to understand the Sun activity in radio region is a part of an initiative of the United Nations together with NASA in order to support developing countries participating in ‘Western Science’ research. Realize how important for us to keep doing a research about the solar bursts, by using the new radio spectrometer, CALLISTO (Compound Low Cost Low Frequency Transportable Observatories) spectrometer. Malaysia is one of the earliest country from South-East Asia (ASEAN) that involve this research. One of the advantages to start the solar monitoring in Malaysia is because our strategic location as equator country that makes possible to observing a Sun for 12 hours daily throughout a year. We strongly believe that Malaysia as one of contributor of solar activity data through E-CALLISTO network. This is a very good start for developing a radio astronomy in Malaysia. With the implementation of 45 MHz - 870 MHz CALLISTO systems and development of solar burst monitoring network, a new wavelength regime is becoming available for solar radio astronomy. Overall, this article presents an overview of optical and radio astronomy in Malaysia. With the present level of the international collaboration, it is believed that the potential involvement of local and international scientist in solar astrophysics will increase.

Keywords: Sun; radio emission; solar radio burst; Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy in Transportable Observatories (CALLISTO); solar flares; Coronal Mass Ejections (CMEs); space weather

1. INTRODUCTION

A new solar cycle of 24th has started since 4th January 2008. It is believed that the 24th solar cycle will be less energetic than the last maximum in 2002 – 2003. Overall, energetic eruptions seem to be less frequent in cycle 24 as shown by the lower number of type II radio bursts, full halo CMEs, and interplanetary shocks. The profile of cycle 24 was determined by

the maximum phase of cycle 23 and the deep minimum of the preliminary phase of cycle 24. Decade observations have also revealed that solar protons could sometimes be accelerated up to tens of GeV in some intense solar energetic process. The latest observations are extremely deficient in the radio and X-ray synoptic and diagnostic influence on these coronal phenomena rich of physics they could reveal.

A number of dedicated studies of the solar radio burst have made great progress in more than a decade beginning with ground observation and become one of the most significant current discussions on space weather issue. The solar flare and CMEs (Coronal Mass Ejections) that can affect life on the surface of the Earth, particularly the increasingly technologically sophisticated devices that are part of modern life [1]. Solar radio observation has been carried out since 1944 when J.S Hey discovered that the Sun emits radio waves [2]. This radio region covers from 15 MHz to 30 GHz while optical region from 1.3343×10^{15} Hz – 2.3349×10^{15} Hz [3].

The Coronal Mass Ejections (CMEs), a multi-thermal radiation has been studied extensively since 1970s. The CME phenomenon was discovered only in 1971 [4] but has become the most important form of solar activity because it is the most energetic phenomena on the Sun with a wide range influence throughout the heliosphere. The front speeds could exceed up to 3000 km/s [5-7]. As the largest scale eruptive phenomenon in the solar atmosphere, it can be observed as enhanced brightness propagating out from coronal-loop-sized scale (10^4 km), expand to cover a significant part of the solar surface which is responsible for the most extreme space weather effects at Earth. This phenomenon can exhibit a variety of forms, some having the classical “three-part” structure [8].

Previous study shown that CMEs associated with solar flares have a higher median speed than those associated with eruptive filaments and that the median speed of CMEs associated with strong flares is higher than that of weak-flare-associated CMEs [9,10]. Solar flare is considered as a high energetic and complicated phenomenon in which mass eruptions occur, energetic particles are generated and highly energy radiations are emitted [11,12]. During a flares, large quantities of energy are transferred between the corona and chromosphere through thermal conduction, non-thermal particle beams, radiation transport and mass motions [13-15]. This event is triggered by fast drift of individual sunspot proper motion within the complex magnetic configuration due to instabilities of equilibrium of coronal magnetic field [16,17].

In this paper, our discussion of the development solar radio astronomy in Malaysia will be highlighted. This is not only from scientific aspects, it is also covered from antenna design to communication and radar technologies [18-21]. Malaysia becomes the 19th countries that involve this research [22]. We started by proposing this research in early 2011, through the National Space Agency of Malaysia (ANGKASA), University of Malaya (UM), National University of Malaysia (UKM) and the MARA University of Technology (UiTM). Previous studies investigated the radio frequency interference (RFI) [23,24]. In the future, we plan to implement the method of the Very Long Baseline Interferometer (VLBI) observations in Malaysia may encounter [25]. By 2011, we have constructed 6 meters Log Periodic Dipole Antenna (LPDA) and successfully set-up the CALLISTO system at National Space Centre, Banting Selangor on 20th February 2012 [26,27]. Start from that, a daily data beginning from 7.30 am to 19.30 pm is automatically stored. This data also accessible on CALLISTO website: <http://www.e-callisto.org/> and can be compared with other sites. Optical observation has started earlier comparing with radio observation. In optical region it covers from 400 – 700 nm while in radio region, we focus from 45 MHz to 870 MHz [28].

The main objective is to monitor the solar activities (solar flares and CMEs) within 24 hours all over the world has positively turned to reality [29,30]. A combination of instrument deployment, analysis and interpretation of space weather data from the deployed instruments in conjunction with space data, and communicate the results to the public play an important role to make the aim become possible [31].

The aims in this paper are based mainly focus on the role of Malaysia as one of significant contributors of solar radio burst data [32]. One of the advantages of solar monitoring in Malaysia is due to our strategic location as equator country that makes possible to observing a Sun for 12 hours daily throughout a year [33]. This makes our data much more consistent with a long duration compared other countries [34]. As an active member of the Working Group of Radio Astronomy in South East Asian Astronomical Network (SEAAN), we are committed to the mission and vision of the group in order to establish effective mechanisms for nurturing and sharing the development and experiences in astronomy research and education among South-East Asian countries [35,36].

2. SCIENTIFIC ACTIVITIES

One of the strategies is to develop the scientific insight necessary to understand the science, and to reconstruct and forecast near-Earth space weather. This includes instrumentation, data analysis, modeling, education, training, and public outreach. The *Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy in Transportable Observatories* (CALLISTO) spectrometer is a heterodyne receiver designing and leading by Christian Monstein and Radio and Plasma Physics Group from ETH Zurich, Switzerland [31]. There are a few designs of a frequency-agile or swept-frequency spectrometers, which are currently in operation in several places, including China [37] Hiraïso [38], Ondrejov [39], Sao Paulo [40] and Trenseldorf [41]. Up to 2014, there are 36 stations around the world that actively observe the Sun routinely. Up to date, this project has successfully achieved more than 90 % target in order to monitor the Sun within 24 hours. Due to 12 hours monitoring, Malaysia almost covered fifty per cent of the CALLISTO data [42]. This make our data more consistent [43,44]. The input impedance, $R_0 = 50 \text{ ohm}$ is chosen for this LPDA antenna [45].

Observational data are limited only a good range of frequency with minimum interference [46]. In order to keep data only with high probability of containing solar radio flares, a filter method also be used from time to time. This data can also be compared with the National Oceanic and Atmospheric Administration (NOAA) list is in an updated state. Data archive allows to store up to 10 TBytes of FIT-files. The archive is physically located at FHNW (Fachhochschule Nordwestschweiz) and managed from ETH in Zurich) [47].

Until now, the number of people interested to pursue research in this field is increasing. The data of solar activity associated with solar burst also become much more relevant. Especially toward 24th year cycle, there are more sun activities that will be observed [48]. In this case, the role of radio region monitoring is very important. We could possible to detect a large flare and Coronal Mass Ejections (CMEs) for instance if we alert on it [49]. Therefore a 24 hour solar monitoring is very significant to fulfill this work [50]. In addition, with international collaboration, there are many advantages that we could gain. We can compare the data, and choose a high quality data if there are a site that polluted by interference by technology application [51-53].

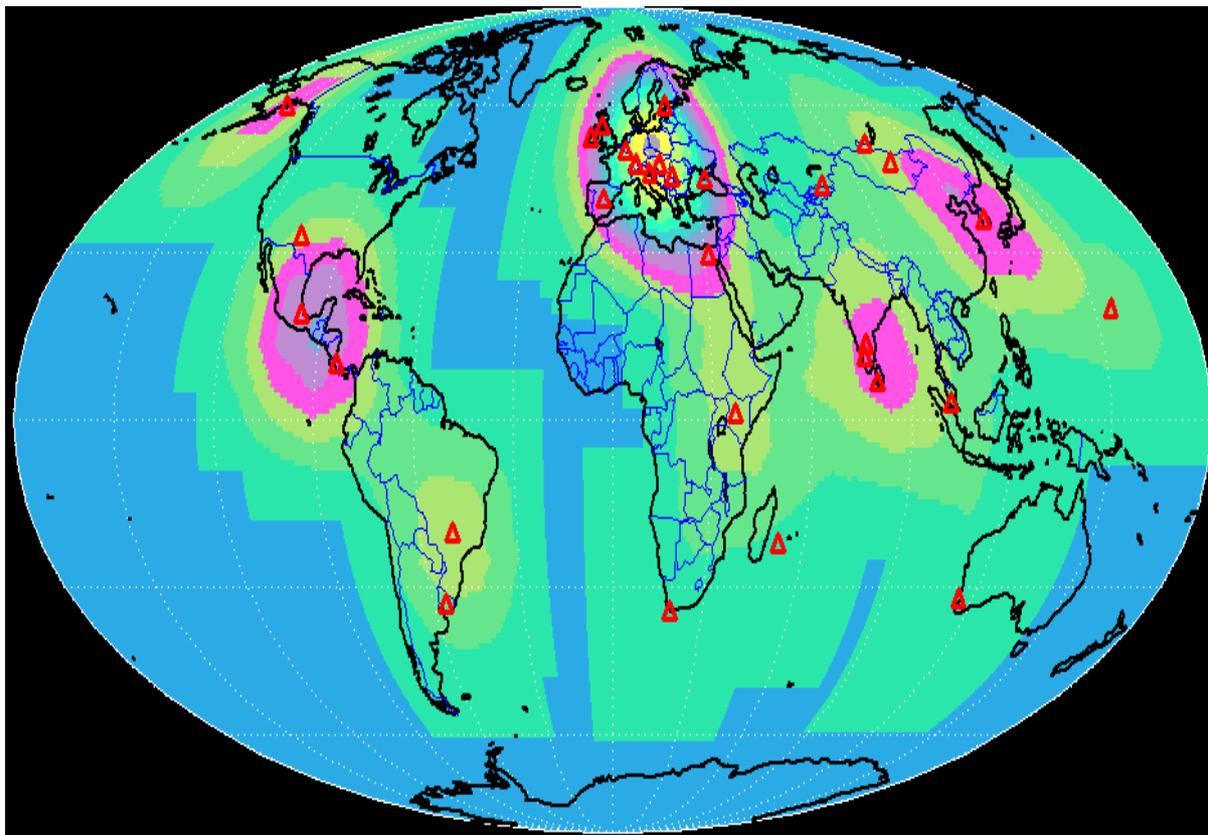


Figure 1. Statistics on the local radio interference (RFI) between 45 MHz and 870 MHz.

Some experiment of the Radio Frequency Interference level (RFI) also have been done by C. Monstein to check the availability of the signal and how impact of the interference could possible affected the signal of the solar burst. In this case, a data has been taken from a single 15 minute FIT-file per location of the e-Callisto network. Based on the results, the South-Korea, Alaska, Mexico and Europe show the highest level of interference. Best ones with low interference level are Spain, Roswell NM, Mauritius, Sri Lanka, Ireland, Mongolia, Krim and Kazakhstan. Purple areas denote to a two-dimensional one sigma level in rfi which are higher than ~ 6 dB over the whole spectrum during 15 minuts of observations (without solar bursts).

Some assumptions need to consider in this testing of evaluation. Firstly the antenna gain with respect to rfi is equal to 0 dB while the noise figure of pre-amplifier ~ 1 dB at reference temperature of ~ 300 Kelvin [54]. The lower the one sigma interference level, the better in general the overall data quality. But it does NOT tell anything about the sensitivity of an individual instrument with respect to a solar burst. Sensitivity concerning solar bursts strongly depends on whether the instrument is connected to a large or to a small antenna and whether it can be positioned to the Sun.

However, as more and more diverse uses for the radio spectrum emerge, the number of signals that may potentially cause interference inexorably increases. The increasing of technological applications exponentially affected the range that is suitable for solar observations. Moreover, the sensitivity of equipment and other ground based noise also produce some minor

impact of the noise level. In addition, population density and site of observations also need to be considered. Nevertheless, the growing demand on electromagnetic spectrum, especially in the radio wavelength cannot be neglected. This scenario has happened all over the world.

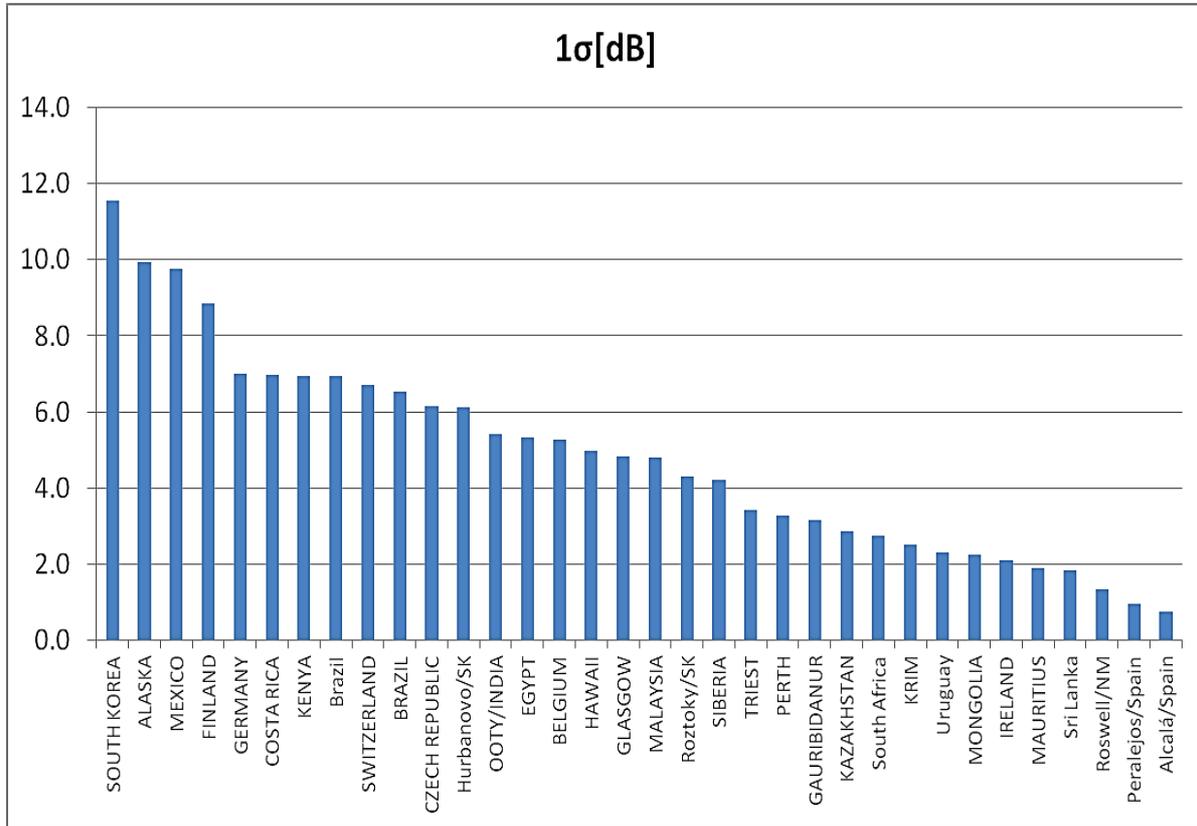


Figure 2. The level of Radio Frequency Interference (RFI) at different sites in e-CALLISTO network.

With the implementation of 45 MHz - 870 MHz CALLISTO systems and the development of solar burst monitoring network, a new wavelength regime is becoming available for solar radio astronomy. Solar activities potentially affect the heliosphere in the short term (space weather) and in the long term (space climate) through numerous physical processes that exhibit similarities in various spatial domains of the heliosphere. Understanding the nature of the motions associated with non-thermal line represents one of the major challenges of high resolution solar studies. On the basis of these works, we suggest that:

1. Future low-frequency imaging arrays are expected to greatly advance our understanding of the bursts and their relation to CMEs.
2. Observations for 24 hours on solar radio burst monitoring by e-CALLISTO, which will make it possible in a short period of time to make a new study focusing on modelling the solar radio data.

Hopefully, these observations can bring upon large scale impact by illuminating the nature of the evolution of the solar burst and the role of that evolution in generating solar activity. The project is under the International Space Weather Initiative (ISWI) which focuses on solar radio research. Perhaps the most relevant cross-calibrations with this thesis were those

with current innovative method of solar instruments, the CALLISTO system as this is used to observe at solar radio energies with independent instruments. The long term statistical data of SRBT II and III described in this work is used to identify the time scales of burst activity associated with solar flares and CMEs activities which can potentially be used for real-time space weather forecasts. Observations are needed at higher frequencies in the THz range, as well as with higher time resolution and sensitivity in the MHz range.

3. CONCLUSIONS

Overall, this article presents an overview of optical and radio astronomy in Malaysia. With the present level of the international collaboration, it is believed that the potential involvement of local and international scientist in solar astrophysics will increase. In this work, we highlighted the potential role of Malaysia as one of the candidate sites that possible gives a good data and focusing on a few aspects such as optimization, and performance evaluation data and visualization. As a conclusion, we strongly believe that Malaysia can be one of a main contributor of solar activity data through the e-CALLISTO network.

This is a very good start for developing a radio astronomy in our country. Therefore, the National Space Centre, Sg. Lang, Selangor is one of the prime candidate sites for the first radio astronomy research. However, there are many aspects need to be considered. Further actions need to be taken to prove solar monitoring studies are very important and should be extended. Besides, collaboration both nationally and internationally is really recommended. In general, this field encompasses many science, engineering and mathematics disciplines. We hope that we can contribute a very relevant data that might possible to answer the dynamical behavior and structure of the Sun. Although the solar activities have experienced rapid growth recently, high-level management of the CALLISTO system has remained successfully manage the storage of data.

Further actions need to be taken to prove solar monitoring studies are very important and should be extended. As sensing and monitoring technology continues to improve, there is an opportunity to deploy sensors in this system in order to improve their management. It is also not easy to maintain the future data seems the numbers of sites are also growing from time to time.

Acknowledgement

This work was partially supported by the PPP UM PV071/2011B grants. Special thanks to C. Monstein from ETH Zurich, Switzerland who set up and gives us training on analyzing the data. Also to National Space Agency and National Space Centre for giving us a site to set up this project and support this project. Solar burst monitoring is a project of cooperation between the Institute of Astronomy, ETH Zurich, and FHNW Windisch, Switzerland, MARA University of Technology and University of Malaya. This paper also used NOAA Space Weather Prediction Centre (SWPC) for the sunspot, radio flux and solar flare data for comparison purpose. The research has made use of the National Space Centre Facility and a part of an initiative of the International Space Weather Initiative (ISWI) program.

Biography

Dr Zety Sharizat Hamidi is currently PhD holder and focused in Solar Astrophysics specifically in radio astrophysics at the University of Malaya. Involve a project under the International Space Weather Initiative (ISWI) and also a senior lecturer in School of Physics and Material Science, at MARA University of Technology, Shah Alam Selangor.

C. Monstein is a senior engineer at Institute of Astrophysics, ETH, Switzerland that develop the e-CALLISTO network.

Dr Nur Nafhatun Md Shariff is a Senior ACIS, MARA University of Technology, Shah Alam Selangor. Her current research is communicating sustainability. She is looking forward for cross-field research i.e. solar astrophysics, light pollution measurement (mapping) and application of technology on sustainability.

References

- [1] S.M. White, *Asian Journal of Physics* 16 (2007) 189-207.
- [2] J.S. Hey, S.J. Parsons, J.W. Phillips, *Monthly Notices of the Royal Astronomical Society* 108 (1948) 354-371.
- [3] Z. Hamidi, U. Ibrahim, U.F. Salwa, Z. Abidin, Z. Ibrahim, N. Shariff, *International Journal of Fundamental Physical Sciences* 3 (2013).
- [4] R. Tousey, The solar corona, in: M.J. Rycroft, S.K. Runcorn (Eds.), *Space Research XIII, Proceedings*, Akademie-Verlag, Berlin, Madrid, Spain, 10 – 24 May, 1972, pp. 713–730.
- [5] N. Gopalswamy, A Global Picture of CMEs in the Inner Heliosphere, in: G. Poletto, Suess, S.T. (Ed.), *Astrophysics and Space Science* 2004, pp. 201–251.
- [6] R.A. Howard, Sheeley Jr, N.R., Michels, D.J.m Koomen, M.J., *J. Geophys. Res.* 90 (1985) 8173-8191.
- [7] O.C. St Cyr, S.P. Plunkett, D.J. Michels, S.E. Paswaters, M.J. Koomen, G.M. Simnett, B.J. Thompson, J.B. Gurman, R. Schwenn, D.F. Webb, E. Hildner, P.L. Lamy, *J. Geophys. Res.* 18 (2000) 169-186.
- [8] R.M.E.a.H. Illing, A.J., *J. Geophys. Res.* 90 (1985) 275-282.
- [9] Z. Hamidi, N. Shariff, *Thermal Energy and Power Engineering* 3 (2014).
- [10] Z. Hamidia, Z. Abidina, Z. Ibrahima, N. Shariffa, C. Monsteinc, *AIP Conf. Proc* 1528 (2013) 55-60.
- [11] Z.S. Hamidi, N. Anim, N.N.M. Shariff, Z.Z. Abidin, Z.A. Ibrahim, C. Monstein, Dynamical structure of solar radio burst type III as evidence of energy of solar flares, in: R.Shukor (Ed.), *PERFIK 2012*, American Institute of Physics, Malaysia, 2013, pp. 11-15.
- [12] Z. Hamidi, N. Shariff, C. Monstein, W.W. Zulkifli, M. Ibrahim, N. Arifin, N. Amran, *International Letters of Chemistry, Physics and Astronomy* 8 (2014) 13-19.
- [13] Z. Hamidi, N. Shariff, C. Monstein, Scenario of Solar Radio Burst Type III During Solar Eclipse on 14 th November 2012, (2014).

-
- [14] Z. Hamidi, N. Shariff, C. Monstein, The Tendencies and Timeline of the Solar Burst Type II Fragmented, (2014).
- [15] Z. Hamidi, N. Shariff, The Propagation of An Impulsive Coronal Mass Ejections (CMEs) due to the High Solar Flares and Moreton Waves, (2014).
- [16] Z. Hamidi, N. Shariff, C. Monstein, W.W. Zulkifli, M. Ibrahim, N. Arifin, N. Amran, *International Letters of Chemistry, Physics and Astronomy* 9 (2014) 8-15.
- [17] Z. Hamidi, N. Shariff, C. Monstein, *International Letters of Chemistry, Physics and Astronomy* 13 (2014) 104-111.
- [18] Z. Hamidi, Z. Ibrahim, Z. Abidin, M. Maulud, N. Radzin, N. Hamzan, N. Anim, N. Shariff, Designing and Constructing Log Periodic Dipole Antenna to Monitor Solar Radio Burst: e-Callisto Space Weather, (2012).
- [19] Z.S.Hamidi, Z. Abidin, Z. Ibrahim, N. Shariff, C. Monstein, *International Journal of Engineering Research and Development* 3 (2012) 36-39.
- [20] Z.S.Hamidi, N.M.Anim, N. N.S.Hakimi, N.Hamzan, A.Mokhtar, N.Syukri, S.Rohizat, I.Sukma, Z.A. Ibrahim, Z.Z.Abidin, N.N.M.Shariff, C.Monstein, *International Journal of Fundamental Physical Sciences* 2 (2012) 4.
- [21] Z.S.Hamidi, N.N.M.Shariff, Evaluation of Signal to Noise Ratio (SNR) of Log Periodic Dipole Antenna (LPDA) Business Engineering and Industrial Applications Colloquium 2013, IEEE, Langkawi, Malaysia, 2013, pp. 434-438.
- [22] N. Hashim, Z. Abidin, U. Ibrahim, R. Umar, M. Hassan, Z. Rosli, Z. Hamidi, Z. Ibrahim, Radio Astronomy in Malaysia: Current Status and Outreach Activities, *Astronomical Society of the Pacific Conference Series*, 2011, pp. 355.
- [23] Z.S.Hamidi, Z.Z.Abidin, Z.A. Ibrahim, N.N.M. Shariff, *AIP Conference Proceedings* 1454 (2012) 43.
- [24] Z.S.Hamidi, N.N.M.Shariff, R.Umar, *Malaysia Thailand Journal of Physics* 3 (2012) 6.
- [25] Z.Z. Abidin, Radio Astronomy Research in Malaysia: Past, Present and Future., *Proc. of Space Science and Communication*, 2009, pp. 179-181.
- [26] Z.S. Hamidi, N.N.M. Shariff, C. Monstein, *The International Journal of Engineering* 1 (2012) 3.
- [27] Z.S.Hamidi, Z. Abidin, Z. Ibrahim, C. Monstein, N. Shariff, *International Journal of Fundamental Physical Sciences* 2 (2012) 32-34.
- [28] Z. Hamidi, S. Chumiran, A. Mohamad, N. Shariff, Z. Ibrahim, N. Radzin, N. Hamzan, N. Anim, A. Alias, *American Journal of Modern Physics* 2 (2013).
- [29] A.O. Benz, C. Monstein, H. Meyer, P.K. Manoharan, R. Ramesh, A. Altyntsev, A. Lara, J. Paez, K.-S. Cho, *Earth Moon and Planets* 104 (2009) 277-285.
- [30] Z. Hamidi, N. Shariff, F.Z. Ulum, Z. Abidin, Z. Ibrahim, Time Series Analysis of Variance of Sunspots in January till September 2010 and Correlation with Sunspots Areas, *International Journal of Astronomy* 1 (2012) 101-104.
- [31] A.O. Benz, C. Monstein, H. Meyers, CALLISTO, A New Concept for Solar Radio Spectrometer, Kluwer Academic Publishers, The Netherland, 2004.

-
- [32] Z. Hamidi, N. Shariff, Z. Abidin, Z. Ibrahim, C. Monstein, *Malaysian Journal of Science and Technology Studies* 9 (2013) 15-22.
- [33] Z.S. Hamidi, Z. Abidin, Z. Ibrahim, N. Shariff, Indication of radio frequency interference (RFI) sources for solar burst monitoring in Malaysia, ICPAP 2011, AIP Publisher, Indonesia, 2012, pp. 6.
- [34] Z.S. Hamidi, N.N.M. Shariff, Z.A. Ibrahim, Z.Z. Abidin, Solar studies in radio emission and optical photometry, University of Malaya Publisher, 2013.
- [35] Z. Hamidi, N. Shariff, C. Monstein, Z. Ibrahim, *International Letters of Chemistry, Physics and Astronomy* 7 (2014) 37-44.
- [36] Z. Hamidi, N. Shariff, C. Monstein, Understanding Climate Changes in Malaysia Through Space Weather Study, *International Letters of Natural Sciences* (2014).
- [37] F.-Y. Xu, Z.-C. Xu, G.-I.Y. Huang, M. Q.-J., X., H.-A. Wu, *Solar Phys.* 216 (2003).
- [38] T. Kondo, T. Isobe, S. Igi, S. Watari, M. Okumaru, *J. Communications Res. Lab.* 42 (1995).
- [39] K. Jiricka, M. Karlicky, O. Kepka, A. Tlamicha, *Solar Phys.* 147 (1993).
- [40] H.S. Sawant, et. al., *Sol. Phys.* 200 (2001).
- [41] G. Mann, A. Klassen, *Astron. Astrophys.* 441 (2005) 319-326.
- [42] Z.S. Hamidi, N. Shariff, Z. Abidin, Z. Ibrahim, C. Monstein, *Middle-East Journal of Scientific Research* 12 (2012) 6.
- [43] Z. Hamidi, N. Shariff, C. Monstein, First Light Detection of A Single Solar Radio Burst Type III Due To Solar Flare Event, (2014).
- [44] R. Umar, et. al., *Middle East Journal of Scientific Research* 14 (2013) 861-866.
- [45] Z.S. Hamidi, N.N.M. Shariff, *International Journal of Science and Mathematics* 2 (2014) 3.
- [46] Z. Hamidi, N. Shariff, C. Monstein, *International Letters of Chemistry, Physics and Astronomy* 10 (2014) 38-45.
- [47] A.O. Benz, M. Guedel, H. Isliker, S. Miskowicz, W. Stehling, *Sol. Phys.* 133 (1991) 385-393.
- [48] Z. Hamidi, N. Shariff, C. Monstein, Statistical Study of Nine Months Distribution of Solar Flares, (2014).
- [49] Z. Hamidi, N. Shariff, C. Monstein, Disturbances of Solar Eruption From Active Region AR1613, (2014).
- [50] Z. Hamidi, N. Shariff, C. Monstein, *International Letters of Chemistry, Physics and Astronomy* 13 (2014) 144-154.
- [51] R. Umar, Z.Z. Abidin, Z.A. Ibrahim, M.S.R. Hassan, Z. Rosli, Z.S. Hamidi, *AIP Conference Proceedings* 1454 (2012) 39.

- [52] Z.S. Hamidi, Z.Z. Abidin, Z.A. Ibrahim, N.N.M. Shariff, U.F.S.U. Ibrahim, R. Umar, Preliminary analysis of investigation Radio Frequency Interference (RFI) profile analysis at Universiti Teknologi MARA, IEEE, 2011, pp. 311-313.
- [53] N. Anim, Z. Hamidi, Z. Abidin, C. Monstein, N. Rohizat, Radio frequency interference affecting type III solar burst observations, 2012 NATIONAL PHYSICS CONFERENCE: (PERFIK 2012), American Institute of Physics, 2013, pp. 82-86.
- [54] Z. Hamidi, N. Shariff, Evaluation of signal to noise ratio (SNR) of log periodic dipole antenna (LPDA), Business Engineering and Industrial Applications Colloquium (BEIAC), 2013 IEEE, IEEE, 2013, pp. 434-438.

(Received 02 August 2014; accepted 12 August 2014)